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NUMERICAL ALGORITHMS FOR PARALLEL AND VECTOR COMPUTERS:

AN ANNOTATED BIBLIOGRAPHY

Prepared By

William G. Poole, Jr.

and

Robert G. Voigt

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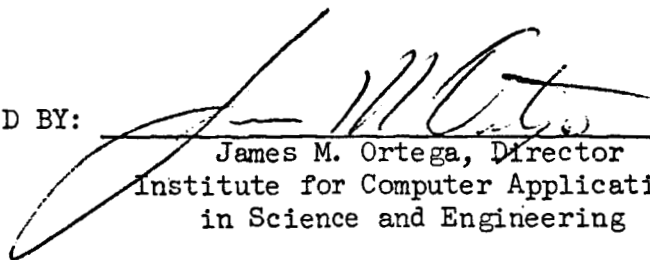
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APPROVED BY:

James M. Ortega, Director
Institute for Computer Applications
in Science and Engineering

Introduction

During the last few years considerable effort has been spent on the development of parallel and vector computers and corresponding numerical algorithms; however, much of this work has not appeared in the standard journals perused by numerical analysts. The intent of this bibliography is to collect all references that might be of interest to someone developing numerical algorithms for parallel and vector computers. Consequently, this bibliography is complete in the area of numerical analysis to the best of the compilers' knowledge. The other categories are not meant to be complete; instead, those entries are simply sources of related information for the interested reader.

Precise definitions of parallel and vector computers will not be given here. They can be found in articles listed in category 6.21 of this bibliography. Stated very briefly, a parallel computer is one which has the capability of performing several operations simultaneously. Contemporary examples are the ILLIAC IV (built by Burroughs Corporation and now located at NASA Ames Research Center) and the C.mmp (composed of several Digital Equipment Corporation PDP-11's and being developed at Carnegie-Mellon University).

In a vector computer the approach is not one of parallel execution of instructions but rather one of streaming vectors of operands through an arithmetic unit functionally divided into subunits. Each subunit has a particular task which it performs as part of the instruction. Examples of vector computers are the STAR-100 (built by Control Data Corporation) and the ASC (built by Texas Instruments, Inc.).

In this bibliography, SIMD will refer to a computer with a single instruction stream and multiple data stream (e.g., ASC, ILLIAC IV, STAR) while MIMD will refer to a multiple instruction stream and multiple data stream (e.g., C.mmp). The key difference in the two types is that the MIMD computer can execute different instructions simultaneously while the SIMD cannot.

Conferences, books and surveys

The Symposium on Complexity of Sequential and Parallel Numerical Algorithms held at Carnegie-Mellon University at Pittsburgh, Pennsylvania, May 16-18, 1973 was probably the first conference with a significant number of papers concerned with the topic of this bibliography. A book edited by J. F. Traub (see category 5.10) contains the invited papers. The Second Langley Conference on Scientific Computing: Numerical Methods for Parallel and Vector Processors held at Virginia Beach, October 21-22, 1974 was also relevant. The survey article by W. L. Miranker (see category 5.10) is an excellent description of the state of the art in late 1970.

Organization

The bibliography consists of two parts. The first part is the listing of all included entries and their corresponding annotations. Where applicable Computing Review numbers (CR) and Mathematical Review numbers (MR) are cited. The entries are classified according to the Computing Reviews classification system which appears periodically in Computing Reviews (most recently in vol. 14, no. 12, December 1973, pages 601-602). In this bibliography category 5, Mathematics of Computation, appears first because it is the primary area of interest. Within each category the entries are listed

alphabetically by first author. At the end of many of the categories

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    AN ALGORITHM FOR SOLVING A TRIDIAGONAL LINEAR SYSTEM OF
    N EQUATIONS ON A SIMD COMPUTER USING RECURSIVE DOUBLING
    IS PRESENTED. FOR N PROCESSORS THE TIME IS PROPORTIONAL
    TO LOG(N). THE ALGORITHM IS NOT AS ATTRACTIVE FOR A
    VECTOR PROCESSOR.
    CR 25,970.

STONE, HAROLD S.
    PARALLEL TRIDIAGONAL SOLVERS
        TECHNICAL REPORT NO. 79, DIGITAL SYSTEMS LABORATORY,
        STANFORD UNIV., STANFORD, CALIF.,1974.
    THE AUTHOR DISCUSSES SEVERAL ITERATIVE AND DIRECT METH-
    ODS FOR SOLVING TRIDIAGONAL LINEAR SYSTEMS ON SIMD COM-
    PUTERS. COMPARISONS ARE MADE IN TERMS OF OPERATION
    COUNTS.

TRAUB, JOSEPH F.
    ITERATIVE SOLUTION OF TRIDIAGONAL SYSTEMS ON PARALLEL
    OR VECTOR COMPUTERS
        IN COMPLEXITY OF SEQUENTIAL AND PARALLEL NUMERICAL
        ALGORITHMS, J.F. TRAUB(ED.), ACADEMIC PRESS, NEW
        YORK,1973,49-82.
    THE AUTHOR DESCRIBES A TECHNIQUE FOR SOLVING LINEAR SYS-
    TEMS IN WHICH THE USUAL RECURRENCE RELATIONS ARE RE-
    PLACED WITH ITERATIONS. THESE ITERATIONS MAY BE CARRIED
    OUT IN PARALLEL ON A SIMD COMPUTER.

SEE ALSO BUZBEE (5.17)
            BUZBEE ET AL. (5.17)
            DORN ET AL. (5.10)
            DORR (5.17)
            ERICKSEN (5.17)
            HAYES (5.17)
            HOCKNEY (5.17)
            KUCK (4.30)
            MIRANKER (5.10)
            MORICE (5.17)
            MURAOKA ET AL. (5.25)
            NOOR ET AL. (3.23)

ROSENFELD (4.32)
ROSENFELD ET AL. (5.17)
RUDSINSKI (5.17)
STAFFORD ET AL. (3.24)
STONE (5.10, PARALLEL ...)

5.15   NONLINEAR AND FUNCTIONAL EQUATIONS

ABERTH, OLIVER
ITERATION METHODS FOR FINDING ALL ZEROS OF A POLYNOMIAL
SIMULTANEOUSLY
MATH. COMP. 27(1973),339-344.
QUADRATICALLY AND CUBICALLY CONVERGENT METHODS ARE GIVEN
THAT   EXHIBIT A DEGREE OF PARALLELISM EQUAL TO THE DE-
GREE OF THE POLYNOMIAL.   A TECHNIQUE IS INCLUDED THAT
PREVENTS DIFFERENT APPROXIMATIONS FROM CONVERGING TO THE
SAME ROOT.

AVRIEL, M. AND WILDE, D.J.
OPTIMAL SEARCH FOR A MAXIMUM WITH SEQUENCES OF SIMUL-
TANEOUS FUNCTION EVALUATIONS
MANAGEMENT SCI. 12(1966),722-731.
AN OPTIMAL SEARCH PROCEDURE FOR FINDING THE MAXIMUM OF A
UNIMODAL FUNCTION IS DESCRIBED.   THIS PROCEDURE INVOLVES
PERFORMING K SIMULTANEOUS FUNCTION EVALUATIONS WITH THE
SPEED OF COMPUTATION INCREASING LOGARITHMICALLY AS A
FUNCTION OF K.   FOR ANOTHER DISCUSSION OF THE SAME IDEA
SEE R.M. KARP AND W.L. MIRANKER.

CHAZAN, D. AND MIRANKER, WILLARD L.
A NONGRADIENT AND PARALLEL ALGORITHM FOR UNCONSTRAINED
MINIMIZATION
SIAM J. CONTROL 8(1970),207-217.
THE AUTHORS DESCRIBE A METHOD FOR UNCONSTRAINED MINIMI-
ZATION IN WHICH AT EACH CYCLE M MINIMIZATIONS ARE PER-
FORMED IN PARALLEL WHERE M IS THE DIMENSION OF THE UN-
DERLYING LINEAR SPACE.
MR (43)1390.

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BOUNDS ON ORDER AND OSTROWSKI EFFICIENCY FOR INTER-
POLATING ITERATION ALGORITHMS
UCRL-72238, LAWRENCE RADIATION LABORATORY, UNIVER-
SITY OF CALIFORNIA, LIVERMORE, CALIFORNIA,1969.
THE AUTHOR CONTINUES THE INVESTIGATION OF INTERPOLATORY
ITERATION FUNCTIONS STUDIED BY FELDSTEIN AND FIRESTONE.

FELDSTEIN, M. ALAN AND FIRESTONE, ROGER M.
HERMITE INTERPOLATORY ITERATION THEORY AND PARALLEL
NUMERICAL ANALYSIS
REPORT, DIVISION OF APPLIED MATHEMATICS, BROWN UNIV..

PROVIDENCE, RHODE ISLAND,1967.
THIS PAPER DERIVES THE ORDER OF CONVERGENCE FOR ALL POS-
SIBLE HERMITE POLYNOMIAL INTERPOLATORY ITERATION FUNC-
TIONS. FOR ONE CLASS OF METHODS A PARALLEL MODE OF EXE-
CUTION IS STUDIED. MIMD PROCESSORS SIMULTANEOUSLY EVAL-
UATE THE FUNCTION AND ITS DERIVATIVES.

GRAU, A.A.
THE SIMULTANEOUS NEWTON IMPROVEMENT OF A COMPLETE SET
OF APPROXIMATE FACTORS OF A POLYNOMIAL
    SIAM J. NUMER. ANAL. 8(1971),425-438.
AN ITERATIVE TECHNIQUE BASED ON NEWTONS METHOD FOR IM-
PROVING AN APPROXIMATE FACTORIZATION OF A POLYNOMIAL OF
DEGREE N IS GIVEN. THE PARALLELISM ARISES IN THE SOLU-
TION OF AN NXN LINEAR SYSTEM AT EACH STEP.
CR 22,817, MR (44)3484.

KARP, RICHARD M. AND MIRANKER, WILLARD L.
PARALLEL MINIMAX SEARCH FOR A MAXIMUM
    J. COMBINATORIAL THEORY 4(1968),19-35.
THIS PAPER IS SIMILAR TO THAT OF M. AVRIEL AND D.J.
WILDE (5.15).
MR (36)3494.

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ON THE EFFICIENCY OF PARALLEL ITERATIVE ALGORITHMS FOR
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    TECHNICAL REPORT, DEPT. OF COMPUTER SCIENCE, CARNEGIE
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LAM, PING Y. AND POOLE, WILLIAM G. JR.
THE CONVERGENCE OF A PARALLEL ANALOGUE OF THE BISECTION
METHOD
    TECHNICAL REPORT 3, NR044-459, COLLEGE OF WILLIAM
    AND MARY,1973.
IN THIS NOTE THE AUTHORS FIND THE EXACT NUMBER OF ITERA-
TIONS REQUIRED FOR CONVERGENCE OF A PARALLEL BISECTION
METHOD APPROPRIATE FCR A SIMD COMPUTER. THE TECHNIQUE
WAS FIRST DESCRIBED BY G. S. SHEDLER(5.15).

LARSON, ROBERT E. AND TSE, EDISON
PARALLEL PROCESSING ALGORITHMS FOR THE OPTIMAL CONTROL
OF NONLINEAR DYNAMIC SYSTEMS
    IEEE TRANS. COMPUTERS C-22(1973),777-786.
THIS PAPER DESCRIBES THE CONTINUING EFFORT IN THE DEVEL-
OPMENT OF ALGORITHMS FOR SOLVING OPTIMAL CONTROL PROB-
LEMS ON A WIDE RANGE OF PARALLEL PROCESSORS. THE BIBLI-
OGRAPHY OF 44 ENTRIES CONTAINS MANY PAPERS (NOT INCLUDED
IN THIS BIBLIOGRAPHY) WHICH DEAL WITH APPLICATIONS.

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HIGH ORDER SEARCH METHODS FOR FINDING ROOTS
RC-4585, IBM WATSON RESEARCH CENTER, YORKTOWN
HEIGHTS, NEW YORK.1973 (TO APPEAR IN J. ASSOC.
COMPUT. MACH.)
THIS PAPER DESCRIBES A CLASS OF SEARCH ALGORITHMS WHICH
GENERALIZE THE BISECTION METHOD. PARALLELISM ARISES
IN SIMULTANEOUS FUMCTION EVALUATIONS. THE ALGORITHMS
REQUIRE KNOWLEDGE OF BOUNDS ON DERIVATIVES OF THE
FUNCTION WHOSE ZERO IS SOUGHT.

MIRANKER, WILLARD L.
PARALLEL METHODS FOR APPROXIMATING THE ROOT OF A
FUNCTION
IBM J. RES. DEVELOP. 13(1969),297-301.
THIS PAPER DESCRIBES METHODS FOR APPROXIMATING A ROOT OF
A ONE DIMENSIONAL FUNCTION. IF P PROCESSORS ARE AVAIL-
ABLE, P NEW APPROXIMATIONS ARE OBTAINED AT EACH STEP.
HOWEVER THE SPEEDUP OVER ONE PROCESSOR IS SHOWN TO BE
ONLY LOGARITHMIC IN P.
CR 17,699, MR (39)1109.

PATRICK, MERRELL L.
A HIGHLY PARALLEL ALGORITHM FOR APPROXIMATING ALL ZEROS
OF A POLYNOMIAL WITH ONLY REAL ZEROS
COMM. ACM 15(1972),952-955.
THIS PAPER DISCUSSES A NEWTON-LIKE ALGORITHM FOR FINDING
REAL ZEROS BASED ON THE FACT THAT THE ZEROS OF THE SEC-
OND DERIVATIVE OF A POLYNOMIAL ARE GOOD STARTING VALUES
FOR NEWTONS METHOD. THE AUTHOR SUGGESTS THAT DIFFERENT
PROCESSORS BE USED SIMULTANEOUSLY FOR APPROXIMATING DIF-
FERENT ZEROS. A MINOR ERROR IS POINTED OUT BY G. C.
SIMMONS IN CACM 17(APRIL 1974),209.

RICE, JOHN
MATRIX REPRESENTATIONS OF NONLINEAR EQUATION
ITERATIONS - APPLICATION TO PARALLEL COMPUTATION
MATH. COMP. 25(1971),639-647.
THIS PAPER PRESENTS A MATRIX REPRESENTATION APPLICABLE
TO MANY ITERATIVE METHODS. METHODS WHICH ARE AMENABLE
TO PARALLEL COMPUTATION ON A MIMD COMPUTER ARE ANALYSED.
MR (46)2850.

SHEDLER, G.S.
PARALLEL NUMERICAL METHODS FOR THE SOLUTION OF EQUATIONS
COMM. ACM 10(1967),286-291.
SEVERAL FAMILIES OF ALGORITHMS FOR APPROXIMATING A ROOT
OF AN EQUATION ARE DESCRIBED. THEY ALL HAVE THE PROPER-
TY THAT, AT EACH ITERATION, SEVERAL NEW APPROXIMATIONS
ARE OBTAINED ON SEPARATE PROCESSORS, THE BEST ONE BEING
RETAINED. THE ALGORITHMS GENERALIZE BISECTION, SECANT.

NEWTON AND MULLERS METHODS.
MR (39)2321.

SHEDLER, G.S. AND LEHMAN, M.M.
PARALLEL COMPUTATIONS AND THE SOLUTION OF POLYNOMIAL
EQUATIONS
RC-1550, IBM WATSON RESEARCH CENTER, YORKTOWN
HEIGHTS, NEW YORK,1966.
THIS PAPER DISCUSSES ALGORITHMS FOR APPROXIMATING ROOTS
OF POLYNOMIAL EQUATIONS ON A SIMD COMPUTER.

SHEDLER, G.S. AND LEHMAN, M.M.
EVALUATION OF REDUNDANCY IN A PARALLEL ALGORITHM
IBM SYSTEMS J. 6(1967),142-149.
THIS PAPER DESCRIBES IN THE CONTEXT OF A SIMD COMPUTER
A PARALLEL ANALOGUE OF THE BISECTION METHOD FOR APPROX-
IMATING ZEROS OF A CONTINUOUS FUNCTION. THE INDIVIDUAL
PROCESSORS ARE USED FOR EVALUATING THE FUNCTION, SIMUL-
TANEOUSLY, AT SEPARATE POINTS.
CR 13,868.

STRAETER, TERRY A.
A PARALLEL VARIABLE METRIC OPTIMIZATION ALGORITHM
TN D-7329, NASA LANGLEY RESEARCH CENTER, HAMPTON,
VA.,1973.
FOR EACH STEP OF THE AUTHOR-S ALGORITHM, IF P IS THE DE-
GREE OF PARALLELISM ON A SIMD COMPUTER, THEN THE FUNC-
TION AND ITS GRADIENT ARE EVALUATED AT P POINTS, THE
METRIC IS MODIFIED BY P RANK-ONE CORRECTIONS AND A SIM-
PLE UNIVARIANT MINIMIZATION IS CARRIED OUT.

TSE, EDISON AND LARSON, ROBERT E.
PARALLEL ALGORITHMS FOR OPTIMUM NONLINEAR STATE
ESTIMATION
IN PREPRINTS OF TECHNICAL PAPERS, FOURTEENTH JOINT
AUTOMATIC CONTROL CONFERENCE, IEEE,1973,213-223.
THIS PAPER DESCRIBES SEVERAL ALGORITHMS FOR ESTIMATING
THE CONDITIONAL MEAN OF THE STATE VECTOR FOR NONLINEAR
DYNAMICAL SYSTEMS. THE ALGORITHMS ARE APPLICABLE FOR
SIMD COMPUTERS AND ASSOCIATIVE PROCESSORS.

WINGO, DALLAS R.
A MULTIPOINT DESCENT METHOD FOR SOLVING SIMULTANEOUS
NONLINEAR EQUATIONS
IN PREPARATION, INSTITUTE FOR COMPUTER RESEARCH,
UNIV. OF CHICAGO, CHICAGO, ILL.,1974.
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WINOGRAD, S.
PARALLEL ITERATION METHODS
IN COMPLEXITY OF COMPUTER COMPUTATIONS, R.E. MILLER

AND J.W. THATCHER (EDS.),PLENUM PRESS, NEW YORK,
1972,53-60.
THIS PAPER SHOWS THAT THE ADVANTAGE GAINED WHEN K PRO-
CESSORS ARE USED IN PARALLEL IS PROPORTIONAL TO LOG(K)
WHEN LOCATING A SIMPLE ZERO OF A FUNCTION BY ITERATION
METHODS.
CR 24,577.

SEE ALSO MIRANKER (5.10).

5.16   NUMERICAL INTEGRATION AND DIFFERENTIATION

ADAMS, DUANE A.
    A MODEL FOR PARALLEL COMPUTATIONS
        IN PARALLEL PROCESSOR SYSTEMS, TECHNOLOGIES, AND AP-
        PLICATIONS, L. HOBBS ET AL(ED.),SPARTAN BOOKS,NEW
        YORK,1970,311-333.
    A MODEL FOR PARALLEL COMPUTATION, WHICH IS VERY MUCH
    LIKE A FLOW CHART, IS DESCRIBED IN WHICH THE SEQUENCING
    CONTROL IS GOVERNED BY THE FLOW OF DATA. AN EXAMPLE
    USING THE ADAPTIVE TRAPEZOID METHOD FOR NUMERICAL INTE-
    GRATION ILLUSTRATES THE MODEL.

RICE, JOHN R.
    PARALLEL ALGORITHMS FOR ADAPTIVE QUADRATURE I -
    CONVERGENCE
        TECHNICAL REPORT NO. 104, COMPUTER SCIENCE DEPT.,
        PURDUE UNIV., WEST LAFAYETTE, IND.,1973.
    THIS PAPER DESCRIBES A THEORETICAL MIMD COMPUTER IN
    WHICH EACH PROCESSOR ATTACKS THE QUADRATURE PROBLEM ON
    ITS OWN SUBINTERVAL. CONDITIONS ARE GIVEN UNDER WHICH
    THE TOTAL TIME REQUIRED FOR THE ALGORITHM IS PROPORTION-
    AL TO 1/(NO. OF PROCESSORS). A CONVERGENCE THEOREM IS
    INCLUDED.

RICE, JOHN R.
    PARALLEL ALGORITHMS FOR ADAPTIVE QUADRATURE II -
    METALGORITHM CORRECTNESS
        TECHNICAL REPORT NO. 107, COMPUTER SCIENCE DEPT.,
        PURDUE UNIV., WEST LAFAYETTE, IND.,1973.
    THE AUTHOR SHOWS THAT IF AN ALGORITHM CONTAINS CERTAIN
    LISTED ATTRIBUTES THEN THE CONVERGENCE THEOREM OF THE
    PRECEEDING WORK APPLIES. THE PROBLEM OF DELAYS CAUSED
    BY ONE PROCESSOR WAITING ON INFORMATION USED BY ANOTHER
    IS DISCUSSED.

RICE, JOHN R.
    PARALLEL ALGORITHMS FOR ADAPTIVE QUADRATURE III -
    PROGRAM CORRECTNESS
        TECHNICAL REPORT NO. 112, COMPUTER SCIENCE DEPT.,
        PURDUE UNIV., WEST LAFAYETTE, IND.,1974.

IN THIS PAPER THE AUTHOR PRESENTS A COMPUTER PROGRAM IN A FORTRAN-LIKE LANGUAGE AND SHOWS THAT IT HAS ALL OF THE ATTRIBUTES REQUIRED TO APPLY THE CONVERGENCE RESULTS OF THE PRECEEDING TWO PAPERS.

SEE ALSO HOWSER ET AL. (5.14).

5.17 ORDINARY AND PARTIAL DIFFERENTIAL EQUATIONS

BUZBEE, B.L.
> A FAST POISSON SOLVER AMENABLE TO PARALLEL COMPUTATION
>> IEEE TRANS. COMPUTERS C-22(1973),793-796.
> THIS PAPER DESCRIBES A MATRIX DECOMPOSITION TECHNIQUE FOR SOLVING THE DISCRETIZED POISSON EQUATION. THE TECHNIQUE IS HIGHLY PARALLEL AND IS APPLICABLE TO BOTH PARALLEL AND VECTOR MACHINES.

BUZBEE, B.L., GOLUB, G.H. AND NEILSON, C.W.
> ON DIRECT METHODS FOR SOLVING POISSONS EQUATIONS
>> SIAM J. NUMER. ANAL. 7(1970),627-656.
> THE AUTHORS DESCRIBE METHODS FOR SOLVING DISCRETIZED POISSONS EQUATION WITH A VARIETY OF BOUNDARY CONDITIONS. THE METHODS INCLUDE MATRIX DECOMPOSITION AND CYCLIC REDUCTION WHICH MAY BE EFFICIENTLY IMPLEMENTED ON PARALLEL AND VECTOR MACHINES.
> CR 21,925. MR (44)4920.

DORR, F.W.
> THE DIRECT SOLUTION OF THE DISCRETE POISSON EQUATION ON A RECTANGLE
>> SIAM REV. 12(1970),248-263.
> THIS SURVEY ARTICLE INCLUDES DESCRIPTIONS OF SEVERAL METHODS FOR SOLVING THE DISCRETE POISSON EQUATION WHICH MAY BE ADAPTED TO PARALLEL COMPUTERS. THERE IS NO DIRECT REFERENCE TO PARALLEL COMPUTATION. THE BIBLIOGRAPHY CONTAINS 71 ENTRIES.
> MR (42)1353.

ERICKSEN, JAMES H.
> ITERATIVE AND DIRECT METHODS FOR SOLVING POISSONS EQUATION AND THEIR ADAPTABILITY TO ILLIAC IV
>> CAC DOCUMENT 60. CENTER FOR ADVANCED COMPUTATION, UNIV. OF ILLINOIS, URBANA, ILL.,1972.
> THE AUTHOR CONSIDERS IMPLEMENTATIONS OF SEVERAL METHODS FOR SOLVING THE POISSON EQUATION INCLUDING THE IMPLICATIONS OF DIFFERENT STORAGE SCHEMES. TIMINGS ARE GIVEN IN TERMS OF ILLIAC IV CLOCKS FOR PROGRAMS WRITTEN IN GLYPNIR.

GILMORE, P.A.
> NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS

BY ASSOCIATIVE PROCESSING
IN PROC. AFIPS 1971 FALL JOINT COMPUTER CONF.,
411-418.
AFTER A DESCRIPTION OF THE STARAN IV COMPUTER, THE AU-
THOR CONSIDERS STORAGE TECHNIQUES AND COMPUTATION ORGAN-
IZATION FOR A WEATHER FORECASTING PROBLEM SOLVED BY A
TIME MARCHING PROCESS.
CR 22,834.

HAYES, LINDA
COMPARATIVE ANALYSIS OF ITERATIVE TECHNIQUES FOR
SOLVING LAPLACES EQUATION ON THE UNIT SQUARE ON A
PARALLEL PROCESSOR
MASTERS REPORT, DEPT. OF MATHEMATICS, UNIV. OF
TEXAS, AUSTIN, TEXAS,1974.
THIS THESIS DESCRIBES THE RESULTS OF ACTUAL RUNS MADE
WITH SEVERAL ITERATIVE METHODS FOR SOLVING THE DISCRE-
TIZED LAPLACES EQUATION ON THE ASC COMPUTER.

HOCKNEY, R.W.
A FAST DIRECT SOLUTION OF POISSONS EQUATION USING
FOURIER ANALYSIS
J. ASSOC. COMPUT. MACH. 12(1965),95-113.
THE AUTHOR DISCUSSES DIRECT TECHNIQUES FOR SOLVING THE
POISSON EQUATION WITH VARIOUS BOUNDARY CONDITIONS. IN
PARTICULAR THE METHOD OF CYCLIC REDUCTION WHICH IS AP-
PROPRIATE FOR SIMD COMPUTERS IS DESCRIBED.
CR 7975.

KARP, RICHARD M., MILLER, RAYMOND E. AND WINOGRAD, S.
THE ORGANIZATION OF COMPUTATIONS FOR UNIFORM RECURRENCE
EQUATIONS
J. ASSOC. COMPUT. MACH. 14(1967),563-590.
THE PROBLEM OF CONSTRUCTING ALGORITHMS FOR THE SOLUTION
OF UNIFORM RECURRENCE EQUATIONS, A GENERALIZATION OF THE
EQUATIONS ARISING IN FINITE DIFFERENCE APPROXIMATIONS OF
PARTIAL DIFFERENTIAL EQUATIONS, IS DISCUSSED. CERTAIN
OF THE COMPUTATIONS CAN BE DONE IN PARALLEL.
CR 13,264.

KELLER, HERBERT B.
NUMERICAL METHODS FOR TWO POINT BOUNDARY VALUE PROBLEMS
BLAISDELL, LONDON, 1968.
THIS BOOK CONTAINS A DESCRIPTION OF THE TECHNIQUE OF
PARALLEL SHOOTING FOR SOLVING BOUNDARY VALUE PROBLEMS.
THE DEGREE OF PARALLELISM IS EQUAL TO THE NUMBER OF SUB-
INTERVALS INTO WHICH THE ORIGINAL INTERVAL IS DIVIDED.
CR 16,021, MR (37)6038.

KISHI, TADASHI
FORMULATION OF THE BOUNDARY CONDITIONS FOR THE TENSOR

CODE
    UCID-30071, LAWRENCE LIVERMORE LABORATORY, UNIV. OF
    CALIFORNIA, LIVERMORE, CALIF.,1973.
THIS PAPER DESCRIBES THE CONVERSION TO THE ILLIAC IV OF
A CDC 7600 PROGRAM FOR SOLVING A PARTIAL DIFFERENTIAL
EQUATION DESCRIBING STRESS WAVE PROPAGATION.

LAMBIOTTE, JULES J. JR. AND HOWSER, LONA M.
    VECTORIZATION ON THE STAR COMPUTER OF SEVERAL NUMERICAL
    METHODS FOR A FLUID FLOW PROBLEM
        TN D-7545, NASA LANGLEY RESEARCH CENTER, HAMPTON,
        VA.,1974.
    THE AUTHORS DISCUSS THE IMPLEMENTATION OF BOTH IMPLICIT
    AND EXPLICIT METHODS FOR SOLVING A PROBLEM OF TWO DIMEN-
    SIONAL FLOW OF A FLUID IN A SQUARE CAVITY. COMPARISONS
    ARE MADE BASED ON STAR TIMING INFORMATION.

MIRANKER, WILLARD L. AND LINIGER, W. M.
    PARALLEL METHODS FOR THE NUMERICAL INTEGRATION OF
    ORDINARY DIFFERENTIAL EQUATIONS
        MATH. COMP. 21(1967),303-320.
    THE AUTHORS PRESENT PARALLEL INTEGRATION METHODS OF THE
    LINEAR MULTISTEP TYPE WHICH ARE APPROPRIATE FOR A MIMD
    COMPUTER WITH A RELATIVELY SMALL NUMBER OF PROCESSORS.
    RUNGE-KUTTA METHODS ARE ALSO CONSIDERED.
    MR (36)6155.

MORICE, PH.
    CALCUL PARALLELE ET DECOMPOSITION DANS LA RESOLUTION
    D-EQUATIONS AUX DERIVEES PARTIELLES DE TYPE ELLEPTIQUE
        IRIA REPORT,1972.
    THE AUTHOR ADAPTS THE METHODS OF ALTERNATING DIRECTIONS
    AND OVERRELAXATION (POINT AND BLOCK) TO SIMD COMPUTERS
    OF THE ILLIAC IV TYPE. FINITE ELEMENT METHODS ARE ALSO
    DISCUSSED.

NIEVERGELT, J.
    PARALLEL METHODS FOR INTEGRATING ORDINARY DIFFERENTIAL
    EQUATIONS
        COMM. ACM 7(1964),731-733.
    THIS IS POSSIBLY THE FIRST PAPER WRITTEN WHICH EXPLICIT-
    LY DESCRIBED A PARALLEL NUMERICAL ALGORITHM. THE ALGO-
    RITHM SIMULTANEOUSLY INTEGRATES AN ORDINARY DIFFERENTIAL
    EQUATION OVER MANY SMALL INTERVALS AND THEN INTERPOLATES
    THE VALUES TO PIECE TOGETHER THE INTERVALS.
    CR 7334.

OSBORNE, M.R.
    ON SHOOTING METHODS FOR BOUNDARY VALUE PROBLEMS
        J. MATH. ANAL. APPL. 27(1969),417-433.
    THIS PAPER DESCRIBES APPLICATIONS OF THE PARALLEL SHOOT-

ING METHOD TO LINEAR AND NONLINEAR BOUNDARY VALUE PROB-
LEMS. THE PARALLELISM IS NOT ADDRESSED DIRECTLY.
MR (39)6521.

ROSENFELD, J.L. AND DRISCOLL, G.C.
SOLUTION OF THE DIRICHLET PROBLEM ON A SIMULATED PARAL-
LEL PROCESSING SYSTEM
IN PROC. OF THE IFIP CONGRESS 68,1968,499-507.
SEVERAL RELAXATION ALGORITHMS WERE TESTED ON A SIMD SIM-
ULATOR. THE RESULTS ARE REPORTED IN THIS PAPER.
CR 16,580.

RUDSINSKI, L.
PROGRAMS FOR ADI FOR ILLIAC IV
ILLIAC IV DOCUMENT 139, DEPT. OF COMPUTER SCIENCE,
UNIV. OF ILLINOIS, URBANA, ILL.,1967.
THIS PAPER DISCUSSES THE IMPLEMENTATION OF ALTERNATING
DIRECTION IMPLICIT METHODS FOR SOLVING PARTIAL DIFFEREN-
TIAL EQUATIONS ON THE ILLIAC IV.

SCHINDLER, S.
ITERATIONSALGORITHMEN FUR GEWOHNLICHE DIFFERENTIAL
GLEICHUNGEN UND IHRE EIGNUNG ZUR PARALLEL PARALLEL-
ARBEIT MITTELS SYMBOLMANIPULATION
COMPUTING 8(1971), 291-308.
THIS PAPER DISCUSSES SEVERAL ITERATIVE ALGORITHMS FOR
THE ANALYTIC APPROXIMATION OF THE SOLUTION OF A SYSTEM
OF ORDINARY DIFFERENTIAL EQUATIONS USING SYMBOLIC MANIP-
ULATION. THEIR SUITABILITY FOR PARALLEL COMPUTATION IS
ALSO DISCUSSED.

SEE ALSO CARROLL ET AL. (3.16)
KRANSKY ET AL. (3.17)
LAMPORT (4.12)
MIRANKER (5.10)
NOOR ET AL. (3.23)
OGURA ET AL. (3.17)
RAJAN (3.21)
WISHNER ET AL. (3.80)

5.2 METATHEORY

5.24   ANALYSIS OF PROGRAMS - SCHEMATA, SEMANTICS, CORRECTNESS

MILLER, RAYMOND E.
A COMPARISON OF SOME THEORETICAL MODELS OF PARALLEL
COMPUTATION
IEEE TRANS. COMPUTERS C-22(1973),710-717.
THIS PAPER DESCRIBES AND COMPARES PETRI NETS, COMPUTA-
TION GRAPHS AND PARALLEL PROGRAM SCHEMATA AS MODELS FOR
PARALLEL COMPUTATION. AN EXTENSIVE BIBLIOGRAPHY IS IN-
CLUDED.

5.25   COMPUTATIONAL COMPLEXITY - MACHINE-BASED, MACHINE-INDE-
PENDENT, EFFICIENCY OF ALGORITHMS

KUCK, DAVID J.
MULTIOPERATION MACHINE COMPUTATIONAL COMPLEXITY (SOME-
TIMES REFERRED TO AS PARALLELISM IN ORDINARY PROGRAMS)
IN COMPLEXITY OF SEQUENTIAL AND PARALLEL NUMERICAL
ALGORITHMS, J.F. TRAUB(ED.), ACADEMIC PRESS, NEW
YORK,1973,17-47.
THIS PAPER DESCRIBES SOME COMPLEXITY RESULTS OF THE TIME
REQUIRED TO EVALUATE STANDARD EXPRESSIONS IN NUMERICAL
PROGRAMS, EMPIRICAL RESULTS ON THE POSSIBLE SPEEDUP (DUE
TO PARALLEL OPERATION) IN STANDARD PROGRAMS AND IMPLICA-
TIONS FOR COMPUTER ORGANIZATION.

KUCK, DAVID J. AND MURAOKA, YOICHI
BOUNDS ON THE PARALLEL EVALUATION OF ARITHMETIC EXPRES-
SIONS USING ASSOCIATIVITY AND COMMUTATIVITY
IN PROC. SEVENTH ANNUAL PRINCETON CONF. ON INFOR-
MATION SCIENCES AND SYSTEMS,1973,161-168,TO APPEAR
IN ACTA INFORMATICA.
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KUNG, H.T.
NEW ALGORITHMS AND LOWER BOUNDS FOR THE PARALLEL EVALUA-
TION OF CERTAIN RATIONAL EXPRESSIONS
TECHNICAL REPORT, DEPT. OF COMPUTER SCIENCE, CARNEGIE
MELLON UNIV., PITTSBURGH, PA.,1974.
THIS PAPER DISCUSSES ALGORITHMS FOR EVALUATING POLYNOM-
IALS ON A SIMD MACHINE. THE ALGORITHMS ARE SHOWN TO BE
ASYMPTOTICALLY OPTIMAL FOR EVALUATING RATIONAL EXPRES-
SIONS.

MUNRO, IAN AND PATERSON, MICHAEL
OPTIMAL ALGORITHMS FOR PARALLEL POLYNOMIAL EVALUATION
J. COMPUT. SYSTEM SCI. 7(1973),189-198.
THE AUTHORS DISCUSS VARIOUS LOWER BOUNDS ON COMPLEXITY,
AND ALGORITHMS FOR THE EVALUATION OF POLYNOMIALS ON A
MIMD COMPUTER WITH K PROCESSORS. THEY DESCRIBE A NEAR-
OPTIMAL ALGORITHM, PROVIDED THE DEGREE OF THE POLY-
NOMIAL IS GREATER THAN K*LOG(K).
MR (47)6124.

MURAOKA, YOICHI AND KUCK, DAVID J.
ON THE TIME REQUIRED FOR A SEQUENCE OF MATRIX PRODUCTS
COMM. ACM 16(1973),22-26.
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PROCESSORS, THE AUTHORS SHOW THAT MATRICES OF DIMENSION
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CR 25,239.

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ALGORITHMS J. TRAUB(ED.),ACADEMIC PRESS, NEW YORK,
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THIS PAPER DISCUSSES THE CONSEQUENCES, FOR COMPUTERS
LIKE THE STAR-100, THAT START-UP AND OPERATION TIMES
HAVE ON THE DESIGN AND CHOICE OF ALGORITHMS.
CR 26,776.

SEE ALSO BRENT (5.12, ... EVALUATION OF ARITHMETIC ...)
BRENT (5.12, ... EVALUATION OF GENERAL ...)
BRENT ET AL. (5.12)
KUCK ET AL. (5.12, THE PARALLEL ...)
MARUYAMA (5.12, ... EVALUATION OF ARITHMETIC ...)
MARUYAMA (5.14, ... EVALUATION OF MATRIX ...)
MARUYAMA (5.12, ON THE PARALLEL ...)

5.3 COMBINATORIAL AND DISCRETE MATHEMATICS

5.31 SORTING

EVEN, SHIMON
PARALLELISM IN TAPE-SORTING
COMM. ACM 17(1974),202-204.
THE AUTHOR ADDRESSES THE PROBLEM OF SORTING N RECORDS
STORED ON ONE TAPE. TWO ALGORITHMS ARE PRESENTED WHICH
USE P PROCESSORS AND REQUIRE TIME PROPORTIONAL TO
(N*LOG(N))/P.

VALIANT, LESLIE G.
THE INTRINSIC COMPLEXITY OF PARALLELISM IN COMPARISON
PROBLEMS
TECHNICAL REPORT, DEPT. OF COMPUTER SCIENCE,
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ASSUMING THE EXISTENCE OF K PROCESSORS, THE AUTHOR CON-
SIDERS SEVERAL COMPARISON PROBLEMS AND OBTAINS SPEED-UPS
OF ORDER K/(LOG(LOG(K))).

SEE ALSO STONE (5.10, PARALLEL...).

5.32 GRAPH THEORY

CRANE, B.A.
PATH FINDING WITH ASSOCIATIVE MEMORY
IEEE TRANS. COMPUTERS C-17(1968),691-693.
THIS ARTICLE DESCRIBES A HIGHLY PARALLEL ALGORITHM FOR
FINDING THE SHORTEST PATH THROUGH A GRAPH WITH EDGES OF
UNEQUAL LENGTH. THE ALGORITHM EXPLOITS CHARACTERISTICS
OF ASSOCIATIVE MEMORIES.

5.4 MATHEMATICAL PROGRAMMING

5.41 LINEAR AND NONLINEAR PROGRAMMING

LERMIT, R. JONATHAN
A LINEAR PROGRAMMING IMPLEMENTATION
CAC DOCUMENT 46. CENTER FOR ADVANCED COMPUTATION,
UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS,1973.
A MODIFICATION OF THE SIMPLEX ALGORITHM USING CHOLESKY
FACTORIZATION IS GIVEN FOR SOLVING THE LINEAR PROGRAM-
MING PROBLEM. IMPLEMENTATION ON THE ILLIAC IV IS BRIEF-
LY DISCUSSED.

5.42 DYNAMIC PROGRAMMING

CASTI, J., RICHARDSON, M. AND LARSON, ROBERT E.
DYNAMIC PROGRAMMING AND PARALLEL COMPUTING
J. OPTIMIZATION THEORY APPL. 12(1973),423-438.
THE AUTHORS DESCRIBE THE INHERENT PARALLELISM IN DYNAMIC
PROGRAMMING PROBLEMS. IN ADDITION THEY DISCUSS THE
CHARACTERISTICS OF COMPUTER CONFIGURATIONS THAT ENABLE
ONE TO TAKE ADVANTAGE OF THIS PARALLELISM.

GILMORE, P.A.
STRUCTURING OF PARALLEL ALGORITHMS
J. ASSOC. COMPUT. MACH. 15(1968),176-192.
THE FIRST PART OF THIS PAPER DISCUSSES A PARALLEL VER-
SION OF THE DYNAMIC PROGRAMMING TECHNIQUE. THE SECOND
PART DESCRIBES PARSING OF CERTAIN MAD STATEMENTS IN
PARALLEL.

TABAK, DANIEL
COMPUTATIONAL IMPROVEMENT OF DYNAMIC PROGRAMMING
SOLUTIONS BY MULTIPROCESSING TECHNIQUES
IEEE TRANS. AUTOMATIC CONTROL AC-13(1968),596.
THIS NOTE DISCUSSES THE USE OF A PARALLEL SEARCH FOR A
MULTIDIMENSIONAL CONTROL VECTOR IN DYNAMIC PROGRAMMING
PROBLEMS.

3 ..........APPLICATIONS...........

3.1 NATURAL SCIENCES

3.16 METEOROLOGY

CARROLL, A.B. AND WETHERALD, R.T.
APPLICATION OF PARALLEL PROCESSING TO NUMERICAL WEATHER

PREDICTION
     J. ASSCC. COMPUT. MACH. 14(1967),591-614.
     THE AUTHORS DESCRIBE THE APPLICATION OF THE SOLOMON II
     COMPUTER TO THE SOLUTION OF A NONLINEAR PARTIAL DIFFER-
     ENTIAL EQUATION MODEL IN NUMERICAL WEATHER FORECASTING.
     CR 16,348.

     SEE ALSO GILMORE (5.17).

3.17   PHYSICS,NUCLEAR SCIENCES

     KRANSKY, VALERE, GIROUX, E. DICK AND LONG, GARY A.
          PARALLEL IMPLEMENTATION OF A TWO-DIMENSIONAL MODEL
               IN PROC. OF THE 1973 SAGAMORE COMPUTER CONFERENCE ON
               PARALLEL PROCESSING, T. FENG (ED.), SYRACUSE UNIV.
               PRINTING PRESS (AVAILABLE FROM IEEE),1973,66-77.
          THE AUTHORS CONSIDER THE PROBLEM OF REPROGRAMMING A
          LARGE TWO DIMENSIONAL PHYSICAL SIMULATION MODEL CALLED
          TEMP FOR THE STAR-100. THE EQUATIONS ARE LAGRANGIAN AND
          THE DIFFERENCE SCHEME IS EXPLICIT.

     OGURA, MASAKO, SHER, MICHAEL S. AND ERICKSEN, JAMES H.
          A STUDY OF THE EFFICIENCY OF ILLIAC IV IN HYDRODYNAMIC
          CALCULATIONS
               CAC DOCUMENT 59, CENTER FOR ADVANCED COMPUTATION,
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          THE AUTHORS CONSIDER THE EFFICIENCY OF ILLIAC IV FOR
          SOLVING A TWO DIMENSIONAL BERNARD-RAYLEIGH CONVECTION
          PROBLEM AS AN INITIAL AND BOUNDARY VALUE PROBLEM USING
          OVERRELAXATION. TIMING ESTIMATES ARE MADE IN TERMS OF
          ILLIAC IV CLOCKS AND A COMPARISON WITH A CDC 6400 IS
          GIVEN.

     WIRSCHING, J.E. AND ALBERTS, A.A.
          THE APPLICATION OF THE STAR COMPUTER TO PROBLEMS IN THE
          NUMERICAL CALCULATION OF ELECTROMAGNETIC FIELDS
               AFWL-TR-69-165, AIR FORCE WEAPONS LAB, KIRTLAND AFB,
               NEW MEXICO,1969.
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          APPLICATION OF THE ILLIAC IV COMPUTER TO PROBLEMS IN THE
          NUMERICAL CALCULATION OF ELECTROMAGNETIC FIELDS
               AFW-TR-69-195,AIR FORCE WEAPONS LAB, KIRTLAND AFB,
               NEW MEXICO,1969.
          NOT AVAILABLE FOR ANNOTATION.

3.2 ENGINEERING

3.21   AERONAUTICAL, SPACE

RAJAN, S.
A PARALLEL ALGORITHM FOR HIGH SUBSONIC COMPRESSIBLE FLOW
OVER A CIRCULAR CYLINDER
   J. COMPUTATIONAL PHYSICS 12(1973),534-552.
THE AUTHOR CONSIDERS THE PROBLEM OF INVISCID COMPRES-
SIBLE SUPERCRITICAL FLOW OVER A CIRCULAR CYLINDER. IM-
PLEMENTATION OF A FINITE DIFFERENCE SCHEME ON THE ILLIAC
IV IS DISCUSSED INCLUDING SUCH ITEMS AS HANDLING THE
BOUNDARY POINTS AND CHANGING THE MESH SIZE.

3.23   CIVIL

FIELD, E.I., JOHNSON, S.E. AND STRALBERG, H.
SOFTWARE DEVELOPMENT UTILIZING PARALLEL PROCESSING
   INTERNATIONAL SYMPOSIUM ON STRUCTURAL MECHANICS
   SOFTWARE, UNIV. OF MARYLAND, COLLEGE PARK , MARYLAND,
   TO APPEAR 1974.
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NOOR, AHMED K. AND FULTON, ROBERT E.
IMPACT OF THE CDC-STAR-100 COMPUTER ON FINITE ELEMENT
SYSTEMS
   TO APPEAR IN J. STRUCTURAL DIV. AMER. SOC. CIVIL ENG.
   1974.
THE AUTHORS DISCUSS THE INFLUENCE OF STAR-100 FEATURES
ON THE SOLUTION OF LARGE FINITE ELEMENT STRUCTURAL ANAL-
YSIS PROBLEMS. MANY OF THE IDEAS DESCRIBED HAVE APPLI-
CABILITY TO OTHER PROBLEMS SOLVED ON ANY SIMD COMPUTER.

3.24   ELECTRICAL, ELECTRONIC

KNAPP, MORRIS A., ACKINS, GARY M. AND THOMAS, JOHN
APPLICATION OF ILLIAC IV TO URBAN DEFENSE RADAR PROBLEM
   IN PARALLEL PROCESSOR SYSTEMS, TECHNOLOGIES, AND AP-
   PLICATIONS, L. HOBBS ET AL(EDS.),SPARTAN BOOKS,NEW
   YORK,1970,23-70.
THIS PAPER DEALS WITH THE APPLICABILITY OF THE ILLIAC IV
TO THE DATA PROCESSING PROBLEMS OF LARGE PHASED ARRAY
RADAR SYSTEMS USED FOR URBAN DEFENSE.

STAFFORD, D.R. AND MERCADO, F.
APPLICATIONS OF VECTOR AND PARALLEL COMPUTERS TO RADAR
DEFENSE SYSTEMS
   NO. 73-428, AIAA COMPUTER NETWORK SYSTEMS CONF.,1973.
THIS CONTAINS A VERY BRIEF DESCRIPTION OF PARALLEL COM-
PUTERS AND THEIR APPLICABILITY TO RADAR SYSTEMS, INCLUD-
ING A MATRIX MULTIPLY ALGORITHM WITHOUT INNER PRODUCTS.

3.6 ARTIFICIAL INTELLIGENCE

3.60   GENERAL

REDDY, D. RAJ
SOME NUMERICAL PROBLEMS IN ARTIFICIAL INTELLIGENCE -
IMPLICATIONS FOR COMPLEXITY AND MACHINE ARCHITECTURE
IN COMPLEXITY OF SEQUENTIAL AND PARALLEL NUMERICAL
ALGORITHMS, J.F. TRAUB(ED.),ACADEMIC PRESS,NEW YORK,
1973,131-147.
SEVERAL NUMERICAL PROBLEMS, INCLUDING MATRIX INVERSION,
FAST FOURIER TRANSFORM, ZEROS OF POLYNOMIALS AND FUNC-
TION MAXIMIZATION WHICH ARISE IN A SPEECH AND VISION UN-
DERSTANDING PROJECT ARE DISCUSSED.   THEIR SOLUTION ON
THE C.MMP IS PROPOSED.

3.8 REAL-TIME SYSTEMS

3.80   GENERAL

LLOYD, GREGORY AND MERWIN, RICHARD
EVALUATION OF PERFORMANCE OF PARALLEL PROCESSORS IN A
REAL TIME ENVIRONMENT
IN PROC. AFIPS 1973 NATIONAL COMPUTER CONF.,101-108.
THE AUTHORS COMPARE THE PERFORMANCE OF GOODYEAR STARAN,
BELL LABS PEPE AND A CDC 7600 ON THE COMPUTATIONS IN-
VOLVED IN TRACKING INCOMING BALLISTIC TARGETS.   INCLUDED
IS A DISCUSSION OF WAYS TO MEASURE EFFICIENCY OF PARAL-
LEL COMPUTERS.
CR 25,868.

WISHNER, R., DOWNS, H. AND SHECHTER, J.
REAL-TIME COMPUTING TECHNIQUES FOR PARALLEL PROCESSORS
IN PROC. OF THE IFIP CONGRESS 71,1972,704-710.
THE AUTHORS DISCUSS METHODS FOR DATA LAYOUT AND COMPU-
TATION SEQUENCING FOR SOLVING THREE REAL-TIME PROBLEMS
ON THE ILLIAC IV.   THE PROBLEMS ARE RADAR TRACKING OF
SEVERAL TARGETS, COMPUTATION OF PARTIAL SUMS AND SYSTEMS
OF ORDINARY DIFFERENTIAL EQUATIONS.
CR 24,884.

SEE ALSO RUDOLPH (6.21).

3.89   MISCELLANEOUS

DOWNS, H. ROBERT
REAL TIME ALGORITHMS AND DATA MANAGEMENT ON ILLIAC IV
IEEE TRANS. COMPUTERS C-22(1973),773-777.
THIS PAPER CONSIDERS SOME OF THE PROBLEMS ASSOCIATED
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TION CONSIDERED WAS CONTROLLING A PHASED ARRAY RADAR FOR
SEARCHING AND TRACKING OBJECTS.

WANG, GARY Y.

PARALLEL PROCESSORS AND AIR TRAFFIC CONTROL AUTOMATION
IN PROC. OF THE ANNUAL MEETING AND TECHNICAL PROGRAM
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THE AUTHOR DISCUSSES, IN GENERAL TERMS, PARALLEL, ASSOC-
IATIVE AND PIPELINE PROCESSORS. HE THEN DISCUSSES WAYS
OF TRYING TO EVALUATE THE PERFORMANCE THAT A PARTICULAR
COMPUTER ARCHITECTURE MIGHT HAVE FOR AIR TRAFFIC APPLI-
CATIONS.

3.9 MISCELLANEOUS

BALL, J.R., BOLLINGER, R.C. ET AL

ON THE USE OF THE SOLOMAN PARALLEL PROCESSING COMPUTER
IN PROC. AFIPS 1962 FALL JOINT COMPUTER CONF.,
137-146.
NOT AVAILABLE FOR ANNOTATION.

4 ·········SOFTWARE··········

4.1 PROCESSORS

4.12   COMPILERS AND GENERATORS

BAER, J.L. AND BOVET, D.P.

COMPILATION OF ARITHMETIC EXPRESSIONS FOR PARALLEL
COMPUTATIONS
IN PROC. OF THE IFIP CONGRESS 68,1968,340-346.
THIS PAPER DESCRIBES AN ALGORITHM FOR PRODUCING A SYN-
TACTIC TREE HAVING A MINIMUM NUMBER OF LEVELS. ALL OP-
ERATIONS ON THE SAME LEVEL CAN BE PERFORMED IN PARALLEL
PROVIDED THERE ARE SUFFICIENT PROCESSORS WHICH CAN PER-
FORM INDEPENDENT TASKS.

HELLERMAN, H.

PARALLEL PROCESSING OF ALGEBRAIC EXPRESSIONS
IEEE TRANS. ELECTRONIC COMPUTERS EC-15(1966),82-91.
A COMPILER AND MACHINE ORGANIZATION WHICH ARE CAPABLE OF
DETECTING OPPORTUNITIES FOR PARALLEL PROCESSING IN ALGE-
BRAIC EXPRESSIONS AND EXECUTING THESE BY MULTIPLE PRO-
CESSING UNITS OPERATING CONCURRENTLY ARE DESCRIBED.

LAMPORT, LESLIE

THE PARALLEL EXECUTION OF DO LOOPS
COMM. ACM 17(1974),83-93.
THIS PAPER DESCRIBES TWO METHODS FOR EXECUTING FORTRAN
DO LOOPS ON A SIMD COMPUTER IN WHICH DIFFERENT PROCES-
SORS EXECUTE DIFFERENT ITERATIONS OF THE LOOP SIMULTANE-
OUSLY. ONE OF THE METHODS IS IMPLICITLY APPLIED TO THE
GAUSS-SEIDEL METHOD FOR THE DIRICHLET PROBLEM.
CR 26,734.

LITTLE, FRANK STANARD
PARALLEL PROCESSING OF SEQUENTIALLY SPECIFIED ALGORITHMS
PH.D. DISSERTATION, UNIV. OF MICHIGAN, ANN ARBOR,
MICHIGAN,1970.
THIS DISSERTATION CONSIDERS THE PROBLEM OF TRANSLATING
PROGRAMS WRITTEN IN CONVENTIONAL HIGHER LEVEL LANGUAGES
INTO CODE EXECUTABLE ON A MIMD COMPUTER. THE PROBLEM OF
THE CORRECTNESS OF THE CODE IS CONSIDERED.

4.2 PROGRAMMING LANGUAGES

4.20   GENERAL

BAER, J.L. AND RUSSELL, E.C.
PREPARATION AND EVALUATION OF COMPUTER PROGRAMS FOR
PARALLEL PROCESSING SYSTEMS
IN PARALLEL PROCESSOR SYSTEMS, TECHNOLOGIES, AND AP-
PLICATIONS, L. HOBBS ET AL(ED.),SPARTAN BOOKS,NEW
YORK,1970,375-415.
IN THE CONTEXT OF PARALLEL COMPUTATION THIS PAPER RE-
VIEWS MODELS CONCERNED WITH FORMAL ASPECTS OF PARALLEL
PROCESSING, MODELS USING NEW LANGUAGES, MODELS EXTENDING
EXISTING LANGUAGES AND MODELS ATTEMPTING TO RECOGNIZE
PARALLELISM IN EXISTING LANGUAGES.

DRAUGHON, E., GRISHMAN, R., SCHWARTZ, J. AND STEIN, A.
PROGRAMMING CONSIDERATIONS FOR PARALLEL COMPUTERS
IMM 362, COURANT INSTITUTE OF MATH. SCI.,NEW YORK,
NEW YORK,1967.
BASED ON EXPERIENCE GAINED WITH A SIMULATOR THE AUTHORS
DISCUSS QUESTIONS OF STORAGE USAGE, PROGRAM FLOW ORGANI-
ZATION, SYSTEM EFFICIENCY AND HIGHER LEVEL LANGUAGES FOR
PARALLEL COMPUTERS. THE EFFECT ON EFFICIENCY OF IN-
CREASING THE NUMBER OF PROCESSORS AVAILABLE IS REPORTED
FOR SEVERAL REAL PROBLEMS. A CONTINUATION OF THIS WORK
MAY BE FOUND IN E. DRAUGHON ET AL.(4.32).

GOSDEN, J.A.
EXPLICIT PARALLEL PROCESSING DESCRIPTION AND CONTROL IN
PROGRAMS FOR MULTI- AND UNI- PROCESSOR COMPUTERS
IN PROC. AFIPS 1966 FALL JOINT COMPUTER CONF.,
651-660.
THE AUTHOR DISCUSSES SEVERAL TECHNIQUES THAT A PROGRAM-
MER CAN USE IN ORDER TO IDENTIFY PARALLELISM IN PROGRAMS
INCLUDING FORK, JOIN AND PARALLEL FORS AND LOOPS. THE
ARTICLE INCLUDES A LARGE BIBLIOGRAPHY.

4.22   PROCEDURE- AND PROBLEM-ORIENTED LANGUAGES

ABEL, NORMA E., BUDNICK, PAUL P., KUCK, DAVID J., MURAOKA,
YOICHI, NORTHCOTE, ROBERT S. AND WILHELMSON, ROBERT B.
TRANQUIL-A LANGUAGE FOR AN ARRAY PROCESSING COMPUTER
IN PROC. AFIPS 1969 SPRING JOINT COMPUTER CONF.,
57-73.
THIS PAPER DESCRIBES THE HIGHER LEVEL LANGUAGE,
TRANQUIL, THAT WAS DESIGNED FOR THE ILLIAC IV. THE
BASIC STRUCTURE OF TRANQUIL FOLLOWS THAT OF ALGOL, WHILE
THE DATA STRUCTURES AND OPERATORS ARE SIMILAR TO THOSE
OF APL. THE SYNTAX IS SPECIFIED IN AN APPENDIX USING AN
EXTENDED VERSION OF BNF.
CR 17,851.

ANDERSON, J.P.
PROGRAM STRUCTURES FOR PARALLEL PROCESSING
COMM. ACM 8(1965),786-788.
THIS PAPER DESCRIBES THE ADDITION OF SEVERAL COMMANDS TO
THE ALGOL 60 LANGUAGE THAT ALLOW THE USER TO SPECIFY
THE PRESENCE OF PARALLEL PROCESSING.
CR 9730.

OPLER, A.
PROCEDURE-ORIENTED LANGUAGE STATEMENTS TO FACILITATE
PARALLEL PROCESSING
COMM. ACM 8(1965),306-307.
THE STATEMENTS -DO TOGETHER- AND -HOLD- WHICH ALLOW A
PROGRAMMER TO INDICATE SECTIONS OF A PROGRAM EXECUTABLE
IN PARALLEL ARE DESCRIBED.

SCHNECK, PAUL B.
AUTOMATIC RECOGNITION OF VECTOR AND PARALLEL OPERATIONS
IN A HIGHER LEVEL LANGUAGE
SIGPLAN NOTICES 7(1972),45-52.
THIS PAPER DESCRIBES A COMPILER WHICH WILL RECOGNIZE
THOSE FORTRAN STATEMENTS WHICH ARE SUITABLE FOR PARALLEL
OR VECTOR EXECUTION. THIS MAY BE APPLICABLE TO ASC,
ILLIAC IV OR STAR.

WIRTH, N.
A NOTE ON PROGRAM STRUCTURES FOR PARALLEL PROCESSING
COMM. ACM 9(1966),320-321.
THIS NOTE IS A CRITICISM OF THE PAPER BY J.P. ANDERSON
(4.22).

4.3 SUPERVISORY SYSTEMS

4.30   GENERAL

KUCK, DAVID J.
ILLIAC IV SOFTWARE AND APPLICATION PROGRAMMING

IEEE TRANS. COMPUTERS C-17(1968),758-770.
THIS PAPER DISCUSSES THE HIGHER LEVEL LANGUAGE TRANQUIL
AND THREE SAMPLE APPLICATIONS FOR THE ILLIAC IV - SPARSE
MATRIX STORAGE, SUMMATION OF THE COMPONENTS OF A VECTOR
AND MATRIX INVERSION.
CR 15,989.

4.32   MULTIPROGRAMMING,MULTIPROCESSING

AOKI, M., ESTRIN, G. AND MANDELL, R.
ANALYSIS OF COMPUTING-LOAD ASSIGNMENT IN A MULTIPROCES-
SOR COMPUTER
IN PROC. AFIPS 1963 FALL JOINT COMPUTER CONF.,
147-160.
THIS IS POSSIBLY THE FIRST STUDY OF PIPELINE COMPUTER
PERFORMANCE BY SIMULATION. AN N-TH ORDER AITKEN-NEVILLE
BIVARIATE INTERPOLATION SCHEME IS STUDIED ON A CONFIGU-
RATION CONSISTING OF A PIPELINE OF TWO COMPUTERS.
CR 6092.

BAER, J.L.
A SURVEY OF SOME THEORETICAL ASPECTS OF MULTIPROCESSING
COMPUT. SURVEYS 5(1973),31-80.
THIS ARTICLE DISCUSSES THE FOLLOWING ASPECTS
OF PARALLELISM - LANGUAGE FEATURES THAT EXPLOIT PARAL-
LELISM, AUTOMATIC DETECTION OF PARALLELISM BY HIGH-LEVEL
LANGUAGES, MODELS FOR PARALLEL COMPUTATION AND PREDIC-
TION OF PERFORMANCE. IN ADDITION AN APPENDIX BRIEFLY
EXAMINES EXISTING AND PLANNED PARALLEL PROCESSORS. THE
BIBLIOGRAPHY CONTAINS 184 ENTRIES.

DRAUGHON, E., SCHWARTZ, JACOB AND STEIN, A.
INDIVIDUAL AND MULTI-PROCESSING PERFORMANCE CHARACTERIS-
TICS OF PROGRAMS ON LARGE PARALLEL COMPUTERS
IMM 380, COURANT INSTITUTE OF MATH. SCI., NEW YORK,
NEW YORK, 1970.
THIS PAPER REPORTS ON THE EFFECT OF THE NUMBER OF PRO-
CESSORS AVAILABLE FOR A PARTICULAR PROBLEM BY EXAMINING
A LARGE NUMBER OF PROGRAMS RUN ON A SIMULATOR OF A PAR-
ALLEL COMPUTER. FOR MORE INFORMATION ON THIS EFFORT SEE
E. DRAUGHON ET. AL.(4.20).

ROSENFELD, J.L.
A CASE STUDY IN PROGRAMMING FOR PARALLEL PROCESSORS
COMM. ACM 12(1969),645-655.
THIS PAPER IS A STUDY OF SYSTEM BEHAVIOR AND AN EVALUA-
TION OF SYSTEM PERFORMANCE FOR PARALLEL PROCESSING SYS-
TEMS. THE MODEL PROBLEM USED FOR THIS WORK IS THE SOLU-
TION BY CHAOTIC RELAXATION OF A LINEAR SYSTEM ARISING IN
THE STUDY OF ELECTRICAL NETWORKS.

SEE ALSO DRAUGHON (4.20).

4.4 UTILITY PROGRAMS

4.41   INPUT/OUTPUT

DERBY, WILLIAM S.
> A THREE-BUFFER I/O SCHEME FOR ILLIAC IV DISK
>> UCRL-73696, LAWRENCE LIVERMORE LABORATORY, UNIV. OF
>> CALIFORNIA, LIVERMORE, CALIF.,1972.
> THIS PAPER ADDRESSES THE PROBLEM OF BALANCING I/O WITH
> COMPUTATION IN THE ILLIAC IV. SEVERAL BUFFER ORGANIZA-
> TION SCHEMES ARE DESCRIBED.

4.49   MISCELLANEOUS

GONZALEZ, MARIO J. AND RAMAMOORTHY, C.V.
> PROGRAM SUITABILITY FOR PARALLEL PROCESSING
>> IEEE TRANS. COMPUTERS C-20(1971),647-654.
> THIS PAPER DESCRIBES A FORTRAN PROGRAM WHICH ACCEPTS
> SOURCE FORTRAN PROGRAMS AS INPUT AND THEN OUTPUTS INFOR-
> MATION REGARDING THEIR PARALLEL PROCESSABILITY.

KUCK, DAVID J., BUDNIK, PAUL P., CHEN, SHYH-CHING, LAWRIE,
DUNCAN H., TOWLE, ROSS A., STREBENDT, RICHARD E., DAVIS,
EDWARD W. JR., HAN, JOSEPH, KRASKA, PAUL W. AND MURAOKA,
YOICHI
> MEASUREMENTS OF PARALLELISM IN ORDINARY FORTRAN PROGRAMS
>> COMPUTER 7(1974),37-46.
> THE AUTHORS DESCRIBE THE RESULTS OF USING A PL/I PRO-
> GRAM TO ANALYZE A LARGE NUMBER OF (SEQUENTIAL) FORTRAN
> PROGRAMS FOR PARALLELISM. THEIR MODEL COMPUTER IS A
> MIMD WITH AN ARBITRARY NUMBER OF PROCESSORS.

RAMAMOORTHY, C.V. AND GONZALEZ, MARIO J.
> A SURVEY OF TECHNIQUES FOR RECOGNIZING PARALLEL PROCES-
> SABLE STREAMS IN COMPUTER PROGRAMS
>> IN PROC. AFIPS 1969 FALL JOINT COMPUTER CONF.,1-15.
> THE AUTHORS USE THE IDEA OF DIRECTED GRAPHS TO DEVISE A
> SCHEME FOR RECOGNIZING PARALLEL PROCESSABLE TASKS WITHIN
> A SERIAL PROGRAM. A BRIEF SURVEY OF OTHER METHODS FOR
> DETECTING PARALLELISM IS INCLUDED.

6   ....HARDWARE...........

6.0 GENERAL

FENG, T.(EDITOR)
> PROC. OF THE 1973 SAGAMORE COMPUTER CONFERENCE ON
> PARALLEL PROCESSING

SYRACUSE UNIV. PRINTING PRESS (AVAILABLE FROM IEEE).
1973.
THIS IS A COLLECTION OF PAPERS PRESENTED AT THE 1973
SAGAMORE COMPUTER CONFERENCE ON PARALLEL PROCESSING.
MOST OF WHICH ARE HARDWARE ORIENTED.

HANLON, A.G.
CONTENT-ADDRESSABLE AND ASSOCIATIVE MEMORY SYSTEMS - A
SURVEY
IEEE TRANS. ELECT. COMPUTERS EC-15(1966).509-521.
THIS SURVEY DESCRIBES BASIC CONCEPTS. HARDWARE. SOFTWARE
AND APPLICATIONS OF ASSOCIATIVE MEMORY SYSTEMS. THE
BIBLIOGRAPHY CONTAINS 125 ENTRIES.

LORIN, H.
PARALLELISM IN HARDWARE AND SOFTWARE - REAL AND
APPARENT CONCURRENCY
PRENTICE-HALL. ENGLEWOOD CLIFFS. NEW JERSEY.1971.
VARIOUS CONCURRENCY AND PARALLEL FEATURES OF MORE THAN A
DOZEN DIFFERENT COMPUTERS ARE DESCRIBED. A PORTION OF
THE BOOK IS CONCERNED WITH MULTIPROCESSING. MORE THAN
150 REFERENCES ARE CITED.
CR 23.092.

PARHAMI, BEHROAZ
ASSOCIATIVE MEMORIES AND PROCESSORS - AN OVERVIEW AND
SELECTED BIBLIOGRAPHY
PROC. OF IEEE 61(1973).722-730.
THIS PAPER DISCUSSES AND CLASSIFIES 171 REFERENCES AC-
CORDING TO THE CATEGORIES OF ARCHITECTURAL CONCEPTS.
HARDWARE IMPLEMENTATION. SOFTWARE CONSIDERATIONS AND
APPLICATIONS.
CR 26.674.

THURBER, KENNETH J. AND PATTON, PETER C.
THE FUTURE OF PARALLEL PROCESSING
IEEE TRANS. COMPUTERS C-22(1973).1140-1143.
THE AUTHORS ATTEMPT TO COUNTER THE PESSIMISM ABOUT PAR-
ALLEL MACHINES WHICH THEY HAVE ENCOUNTERED. PARALLEL
PROCESSORS SHOULD BE CONSIDERED AS SPECIAL PURPOSE COM-
PUTERS WHICH. WHEN CORRECTLY DESIGNED FOR A PARTICULAR
APPLICATION. CAN PERFORM VERY WELL.

6.2 COMPUTER SYSTEMS

6.20   GENERAL

HOBBS, L.C.. THEIS, D.J.. TRIMBLE, JOEL. TITUS, HAROLD
AND HIGHBERG, IVAR
PARALLEL PROCESSOR SYSTEMS, TECHNOLOGIES, AND
APPLICATIONS

SPARTAN BOOKS, NEW YORK,1970.
THIS BOOK IS A COLLECTION OF PAPERS PRESENTED AT THE
SYMPOSIUM OF THE SAME NAME AT THE NAVAL POSTGRADUATE
SCHOOL, MONTEREY, CALIF. IN 1969.
CR 21,950.

KENEDA, YUKIO
A SURVEY OF PARALLEL PROCESSING AND PARALLEL PROCESSOR
SYSTEMS
REPORT, ELECTROTECHNICAL LABORATORY, TOKYO, FEB.1973.
THIS ARTICLE (IN JAPANESE) SURVEYS PAST AND PRESENT DE-
SIGNS FOR PARALLEL AND VECTOR PROCESSING SYSTEMS. IN-
CLUDED ARE SECTIONS ON APPLICATIONS, OPERATING SYSTEMS
AND LANGUAGES. THE BIBLIOGRAPHY CONTAINS 61 ENTRIES.

MINKER, JACK
AN OVERVIEW OF ASSOCIATIVE OR CONTENT-ADDRESSABLE MEMORY
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COMPUTING REVIEWS 12(1971), 453-504.
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TIONS. A TOTAL OF APPROXIMATELY 800 ENTRIES ARE LISTED.

STONE, HAROLD S. (EDITOR)
INTRODUCTION TO COMPUTER ARCHITECTURE
SCIENCE RESEARCH ASSOCIATES, PALO ALTO, CALIF., TO
APPEAR IN 1975.
THIS TEXTBOOK ON COMPUTER ARCHITECTURE TREATS ARRAY COM-
PUTERS AND MULTIPROCESSORS IN ONE CHAPTER. THE DISCUS-
SION IS TUTORIAL AND DESIGNED FOR PEOPLE NEW TO THE
AREA.

SEE ALSO KOGGE (5.10, MINIMAL...).

6.21   GENERAL-PURPOSE COMPUTERS

BARNES, G.H., BROWN, RICHARD M., KATO, MASO, KUCK, DAVID
J., SLOTNICK, DAVID L. AND STOKES, RICHARD A.
THE ILLIAC IV COMPUTER
IEEE TRANS. COMPUTERS C-17(1968),746-757.
THE LOGIC STRUCTURE AND ORGANIZATION OF THE ILLIAC IV
ARE DESCRIBED AS ENVISIONED IN 1968. THIS CONFIGURATION
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64.
CR 16,308.

BURROUGHS CORPORATION
ILLIAC IV SYSTEMS CHARACTERISTICS AND PROGRAMMING MANUAL
NASA CONTRACTOR REPORT NASA CR 2159, NASA, WASHING-
TON, D.C.,1973.

THIS IS THE ILLIAC IV HARDWARE MANUAL SUPPLIED BY THE
MANUFACTURER. SOME OF THE INFORMATION IS NOW OUT OF
DATE. PROGRAMMERS WILL REQUIRE ADDITIONAL MANUALS.

CONTROL DATA CORPORATION
    CONTROL DATA STAR-100 COMPUTER SYSTEM
        PUBLICATION NO. 60256000, CONTROL DATA CORPORATION,
        ARDEN HILLS, MINNESOTA,1973.
    THIS MANUAL CONTAINS A DETAILED DESCRIPTION OF THE
    STAR-100 CONFIGURATION, PROGRAMMING CONSIDERATIONS AND
    HARDWARE INSTRUCTIONS.

CRANE, B.A., GILMARTIN, M.J., HUTTENHOFF, J.H., RUX, P.J.
AND SHIVELY, R.R.
    PEPE COMPUTER ARCHITECTURE
        IN PROC. OF 1972 IEEE INTERNATIONAL COMPUTER SOCIETY
        CONFERENCE, 1972,57-60.
    THE AUTHORS DESCRIBE BELL LABS PEPE ARRAY PROCESSOR
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        IEEE TRANS. COMPUTERS C-18(1969),800-816.
    THIS PAPER PRESENTS A DETAILED DESCRIPTION OF THE DESIGN
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DENENBERG, STEWART A.
    AN INTRODUCTORY DESCRIPTION OF THE ILLIAC IV SYSTEM, V.1
        CAC ILLIAC IV DOCUMENT 225, CENTER FOR ADVANCED COM-
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    HARDWARE MANUAL LISTED ABOVE.

FLYNN, M.J.
    SOME COMPUTER ORGANIZATIONS AND THEIR EFFECTIVENESS
        IEEE TRANS. COMPUTERS C-21(1972),948-960.
    A HIERARCHICAL MODEL OF COMPUTER ORGANIZATIONS IS DEVEL-
    OPED AND USED TO EXAMINE INTERACTIONS WITHIN A PROCESSOR
    SYSTEM. BOTH SIMD AND MIMD COMPUTERS ARE DISCUSSED. AN
    EXPLANATION OF THE MINSKY CONJECTURE IS GIVEN.

GRAHAM, WILLIAM R.
    THE IMPACT OF FUTURE DEVELOPMENTS IN COMPUTER TECHNOLOGY
        COMPUTERS AND STRUCTURES 1(1971),311-321.
    THIS PAPER COMPARES EXECUTION TIMES OF BASIC ARITHMETIC
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    CDC 7600 AND THE IBM 360/75 AND 360/195. IT BRIEFLY

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HINTZ, R.G. AND TATE, D.P.
    CONTROL DATA STAR-100 DESIGN
        IN PROC. OF 1972 IEEE INTERNATIONAL COMPUTER SOCIETY
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    THE DESIGN OF A HIGHLY PARALLEL COMPUTER ORGANIZATION
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    THE AUTHORS DESCRIBE A CONFIGURATION WITH HIGH RELIABIL-
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MCINTYRE, DAVID E.
    AN INTRODUCTION TO THE ILLIAC IV COMPUTER
        DATAMATION 16(1970),60-67.
    THIS ARTICLE GIVES A SIMPLE INTRODUCTION TO THE ILLIAC
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    THE TOPICS OF COMMUNICATION, PROGRAMMING AND STORAGE.

MURTHA, J.C.
    HIGHLY PARALLEL INFORMATION PROCESSING SYSTEMS
        ADVANCES IN COMPUTERS 7(1966),1-116.
    THE AUTHOR REVIEWS PARALLEL COMPUTERS FROM MACHINE DE-
    SIGN THROUGH SOFTWARE DESCRIPTION INCLUDING PRESENTATION
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RUDOLPH, J.A.
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    PROCESSOR - STARAN
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        241.
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    CR 25,870.

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    LARGE PARALLEL COMPUTERS
        J. ASSOC. COMP. MACH. 13(1966),25-32.
    SEVERAL TYPES OF COMPUTERS INCORPORATING PARALLELISM ARE
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    TATION ARE CONSIDERED.

SLOTNICK, D.L., BORCK, W.C. AND MCREYNOLDS, R.C.
    THE SOLOMON COMPUTER
        IN PROC. AFIPS 1962 FALL JOINT COMPUTER CONF.,97-107.
    THIS PAPER IS AN EARLY DESCRIPTION OF THE SOLOMON ARRAY
    PROCESSOR, THE FORERUNNER OF THE ILLIAC IV.

TEXAS INSTRUMENTS, INC.
    A DESCRIPTION OF THE ADVANCED SCIENTIFIC COMPUTER SYSTEM
        PUBLICATION NUMBER 930034-1, TEXAS INSTRUMENTS,
        INC., AUSTIN, TEXAS,1973.
    THIS MANUAL CONTAINS A DESCRIPTION OF BOTH THE HARDWARE
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    ENTIRE INSTRUCTION SET.

WATSON, W.J.
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    THE AUTHORS DESCRIBE HARDWARE AND SOFTWARE ASPECTS OF
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    LON UNIVERSITY. SOME PROGRAMMING PROBLEMS THAT CAN
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